§2. Development of Multichannel Ultrashort Pulsed Radar Reflectometer for Electron Density Profile Measurement

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Recently we have been developing a new type of reflectometer which uses an ultrashort sub cycle pulse. It is called as an ultrashort pulsed radar reflectometer. An ultrashort pulse has broad band frequency components in Fourier space. It means one ultrashort pulse can take the place of a broad band microwave source.

Currently an impulse of -2.2 V, 23 ps FWHM is used as a source. To extract the desired probing range of the frequency (8 - 40 GHz), we utilize a 500 mm *Ka*-band rectangular waveguide for 26–40 GHz microwaves and a 500 mm *X*-band waveguide for 8–18 GHz. When the impulse is launched into the waveguide, it is transformed to a chirped wave including broad frequency components. The lowest frequency component is determined by the waveguide size. Also higher frequency components than the maximum frequency in the standard frequency band are filtered out by a low pass filter. Therefore we can obtain the microwave of each desired frequency band.

Each obtained chirped microwave is amplified by a power amplifier and launched into the plasma. The incident wave reflects back from the cut-off layers corresponding to each frequency component. The reflected wave is divided and led to the detection stage of each frequency band. *X*-band frequency components are detected directly through each bandpass filter (BPF). *Ka*-band components are detected by a superheterodyne detection system. In a mixer the reflected wave is downconverted by the local microwave frequency of around 42 GHz. The output from the mixer is amplified by the intermediate frequency (IF) amplifier 2–18 GHz and then led to a single-pole double-throw (SPDT) switch. Each IF signal is filtered by 12 BPFs of which the center frequencies are from 3 to 14 GHz. The 12 signals are detected by Schottky barrier diode detectors to obtain the reflected signal pulses. Then TOF measurement is carried out using these pulses.

For the convenient multichannel system we utilize the switching technique. The frequency of the local oscillator is changed from 41.5 to 42.0 GHz with the repetition rate of f_0. A SPDT switch is operated at a $2f_0$ repetition rate. Then the frequency components of the detector output are changed four times in one operation. For example, when the 9 and 10 GHz BPFs are paired, the measurable frequencies are 31.5, 32.0, 32.5, and 33.0 GHz in the incident microwave components. The important advantage is that there is no need for additional TOF measurement electronics. Figure 1 shows an example of frequency switching operation. In this case the local frequency is fixed with 42.0 GHz. Both 5 and 8 GHz BPFs make a pair. The 5 GHz BPF, which has an incident frequency component of 37 GHz, is located after a six-way divider and the 8 GHz BPF, which has an incident frequency component of 34 GHz, is located after another divider. When the level of the switching signal is high, only the 34 GHz signal is passed. Then the same discriminator collects both the 37 GHz signal and the 34 GHz signal.

Currently this reflectometer system operates with the ordinary mode polarization and has 28 channels of which 24 channels are *Ka* band and 4 channels are *X* and *Ku* bands. An example of the temporal behaviors of the TOF of each reflected pulse is shown in Fig. 2. The delay time is defined by the traveling time from the plasma edge, the position of which is calculated using the result of *in situ* calibration and a MHD equilibrium calculation, to each cut-off layer. When the corresponding cut-off layer is generated in the plasma, each reflected wave appears in order.

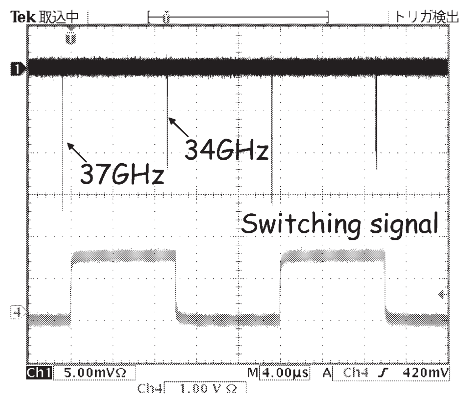

Fig. 1. Example of the frequency switching operation.

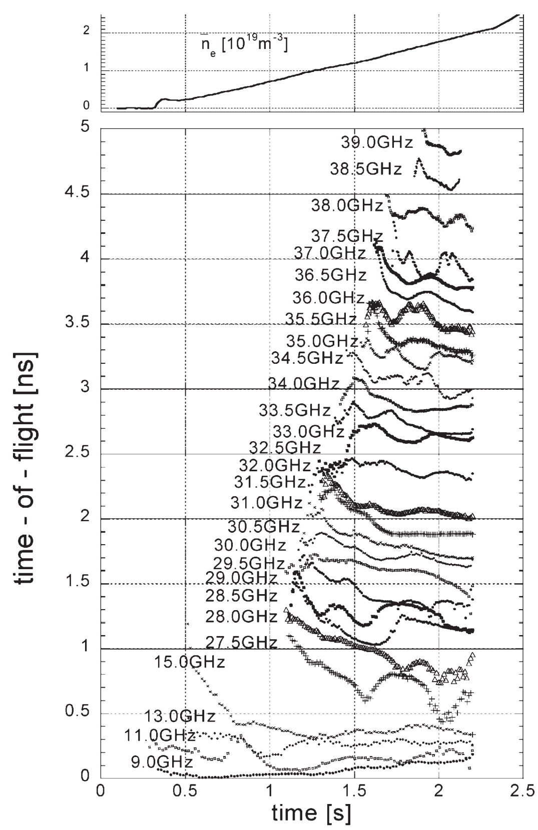

Fig. 2. Time evolution of the averaged density (top) and the delay time of the reflectometer each channel.